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THE USE OF CHLORINE FOR THE CORRECTION OF SLUDGE BULKING IN THE ACTIVATED SLUDGE PROCESS.

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The efficiency of many activated sludge sewage treatment plants is materially affected at times by a diffuse or fluffy condition of the sludge particles, which, in the clarification tank following aeration, results in slow settlement and hence increased volume or "bulking" of the sludge. Consequently, in aggravated cases large amounts of these sludge solids may be carried over the effluent weirs instead of being removed through the bottom sludge outlets. Because this condition admittedly constitutes one of the "weak links" in this method of sewage treatment, our late consultant, Mr. George W. Fuller, recommended the advisability of the Stream Pollution Investigations Station of the Public Health Service undertaking some studies of the biological and biochemical factors involved in sludge bulking.

Extensive microscopical observations of activated sludges have indicated that there are at least two distinct conditions of the sludge floc, either of which when present will cause the sludge to settle with difficulty, if at all. One is a thin, diffuse or spongy, ragged floc, that tends to float because of its relatively large surface area; the other is a floc possibly of moderate or good quality, but heavily infested with thin fungus threads which extend out in all

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directions from the main body and thereby increase greatly the buoyancy of the floc and doubtless separate materially the individual particles as well. All gradations and combinations of these two conditions may occur in specific instances. Thus a floc that is quite fine, ragged and diffuse may be settled in the final clarifier with reasonable success, but if a moderate growth of fungus should appear, the settling process is seriously retarded. The present discussion is confined to the bulking resulting from excessive amounts of fungus in the sludge.

For determination of the physical condition of sludge floc particles, the use of a low power (preferably binocular) microscope, magnifying about 20 or 30 diameters, is most essential. Daily routine observations of the sludge by such an instrument will disclose any progressive changes in floc structure that signify either the oncoming improvement or deterioration of sludge settling quality. By adjusting the substage mirror at a point slightly <u>in front</u> of the optical axis of the microscope to secure a dark field effect, and using a dilution (1 in 40 is suggested) of the sludge in a cell about 1 millimeter deep of the type used for plankton enumeration (with cover-glass adjusted) the floating flocs can be seen clearly outlined against a dark field and any attached fungus may be readily distinguished by reason of the light reflected from their minute filaments, affording a sharp contrast with the surrounding dark field. A true picture of the undistorted floating floc, as it occurs in its natural environment in the clarification tank, is thus obtained.

References in the literature to bulking caused by fungus, including descriptions and characteristics of the causative organism, have been quite frequent. Many means have been suggested to inhibit the growth of the fungus such as the addition of lime, increased aeration, decreased aeration, chlorine, elimination of carbohydrates from the sewage to be treated, etc. One of the difficulties experienced in the use of chemicals for this purpose has been that when applied in a concentration sufficient to destroy the fungus growth, the normal fauna and flora essential for the functioning of activated sludge were killed and the effluent deteriorated rapidly.

Chlorine has been used in connection with the activated sludge process by many investigators. Dallyn and DeLaporte[1] in 1926 reported chlorinating return sludge to give a residual of 0.05 p.p.m. without upsetting plant operation. Apparently in this case the chlorine was used for odor control. In 1929, Bell[4] added bleaching powder to the return sludge at Barnsley, England, at an average rate of 22 p.p.m. available chlorine, and stated that it "has been found very useful in restricting the amount of septic matter returned to the aeration tank." Cascoigne[5] in 1931 reported the use in Canada of bleaching powder applied to return activated sludge to correct disturbances in the process. Heukelekian[6] in 1931 reported increased turbidity in the supernatant liquor due to sterilization of activated sludge with chlorine.

Chlorination of sewage entering activated sludge plants has been tried by many investigators with widely varying results. Goudey[7]

in 1932 reported that, at Pasadena, prechlorination tended to cause bulking.

The Committee on Sewage Disposal of the American Public Health Association[10] reported in 1932 that "although chlorine has been tried by several investigators in an effort to control bulking of activated sludge, there are as many negative as positive results. Hence, its value for this purpose remains unproven."

Experimental Study. Two methods of approach to the problem of fungus growth control seemed feasible. These were: (1) isolation of the organism in pure culture and determination of its growth requirements and possible elimination of essential foods or environmental conditions, and (2) addition of some material in a concentration toxic to the fungus but not to the other microscopic organisms normal to proper functioning activated sludge.

The first of these procedures has thus far not been successful. The fungus has been grown in pure culture, but our efforts to reinoculate it into sewage have failed. Attention was, therefore, directed to the second method of control. Fungus laden, aerated sludge was treated, first in one-liter glass graduates and later in eight-liter bottles in which aeration was provided, with one of a number of toxic materials in varying amounts and these mixtures examined under the microscope after definite intervals of time to observe the effect of the chemicals on the fungus strands, as well as upon the other forms of plankton. Phenol, lime, copper sulphate, iron salts, alum, sulphur, silica gel, activated carbon, sodium sulphite and chlorine were among

the chemicals employed. The most consistently favorable results were obtained with chlorine, which if added in proper proportion, appeared to shrivel the protruding strands of fungus but did not destroy the normal plankton associated with the sludge floc.

Based on these observations, tests were continued on a larger scale in the experimental activated sludge treatment plant when bulking of sludge was experienced. This unit had been operated for several days previous to August 28, 1934 on the fill and draw method. The sludge was in such condition that, after 90 minutes settling, the sludge blanket was only 3 inches below the surface and fungus growths in the floc particles were very abundant. On that date chlorine to the amount of 22.5 p.p.m. was added to the sludge-sewage mixture in the aeration tank and after an interval of 1-1/2 hours standing, observations indicated that the fungus was adversely affected but that other plankton - except stalked ciliates - remained active. After reseeding with sewage-sludge liquor from another unit to the extent of 4 per cent of the tank volume, operation was resumed. The sludge index - $\frac{\text{suspended solids in p.p.m.}}{\text{settleable solids in cc. per liter}}$ - increased from 2.1 to 10.4 by this treatment and continued to improve, reaching 16.3 by September 10, 1934.

Following these favorable results the suggestion was made to Mr. N. W. Smith in charge of the Lima, Ohio, activated sludge plant that the application of chlorine might be of value in retarding the growth of fungus in the activated sludge and thereby improve the bulking condition being experienced. Favorable results were obtained as

recorded by Mr. Smith[12] and chlorination has since constituted an integral part of the treatment at that plant. Mr. Smith, however, made one noted change in the treatment in that he introduced the chlorine into the return sludge and in smaller amounts than had been attempted before.

During the past year chlorine has been frequently used to reduce fungus growths in activated sludge at this station, using Mr. Smith's method of applying small amounts to the return sludge. Results, insofar as fungus control is concerned, were uniformly successful. An improvement in the settling of the floc was always obtained if fungus was present, but if the bulking of the sludge was due in any great degree to the presence of a light, diffuse floc, the improvement was not always sufficient to insure satisfactory operation of the plant. Observations pertinent to these experiments are given in Table I, which lists the conditions at the start, the average amount of chlorine used and its effect as shown by the sludge condition at the end of the experiment.

(Insert Table I.)

These results plainly show that chlorine applied in small amounts to the return sludge reduced fungus growths and so effected an improvement in the sludge. Except in Experiment 5 there was a noticeable improvement in the settling of the sludge in the final clarifier, the sludge blanket level dropped, the effluent improved and the sludge index rose. Experiments 1, 2, and 6 indicate clearly

how plant operation improved with the use of chlorine and how, with cessation of chlorination, after an interval bulking again recurred with attendant operating difficulties. Experiments 1 to 5 inclusive also show clearly that although chlorine reduced the interference with proper settling caused by fungus filaments, this treatment did not cause the floc particles to coagulate and did not aid in controlling the bulking that is due to small, light floc particles of comparatively low specific gravity.

Experiments 6 and 7 were made with intermittent, instead of continuous, chlorination of the return sludge. The chlorine dosages were much lighter than in the other experiments, but were apparently effective in destroying the fungus filaments. These two experiments show the remarkable improvement in sludge settling due to the action of chlorine on fungus filaments attached to large, dense flocs. Experiment 6 also shows the rapid decrease in settling rate of the sludge due to increased fungus growth when chlorination was suspended.

Tables II and III give daily results for Experiments 4 and 6 respectively. It is interesting to note that in Experiment 4 when the chlorine dosage was about 2.5 p.p.m. or .05 per cent on a dry solids basis the sludge settling improved, but when the dosage dropped to 1.7 p.p.m. or less (about .03 per cent of the dry solids) the settling deteriorated. In Experiment 6, however, chlorine in the amount of 0.7 p.p.m. or .01 per cent of the dry solids was ample to effect a marked improvement in the settling. The difference may

be due to the marked dissimilarity in the two flocs.

(Insert Tables II and III.)

In November, 1935, an opportunity was provided to test the use of chlorine for reduction of fungus growths in routine plant operation. The City of Lancaster, Pa., had experienced much trouble with bulking activated sludge at its South Plant and requested aid in solving the problem from the U. S. Public Health Service. After investigation of plant arrangement and conditions, the trial use of chlorine was recommended. The floc was large, very diffuse and apparently loosely bound together with fungus filaments which were present in large amount. Although it was realized that chlorine would not overcome the diffuseness of the floc, it was felt that reduction in the amount of fungus would cause some improvement in the settling of the sludge. The return sludge was chlorinated for four days (November 22 to November 26) at the rate of 4.37 p.p.m. or 0.11 per cent of the dry solids. When chlorination was stopped, the amount of fungus had been greatly reduced and the stalked ciliates, chiefly epistylis, were beginning to show the effect of the chlorine. During the chlorination of the sludge an unexpected, interesting increase of turbidity of the effluent occurred. The chlorine apparently destroyed some of the fungus strands that had previously loosely held the floc material together. The average size of the floc decreased and considerable very fine floc material, much of it nearly colloidal, appeared in the effluent. Before chlorination was stopped, much of this loosened material had washed out of the floc and the effluent was beginning to clear. After chlorination was stopped, the turbidity continued to

decrease.

Since November 26th, chlorine has been used regularly, but in smaller amounts, to prevent excessive growths of fungus. At the end of the year, December 31, 1935, the treatment has continued successful, the sludge is settling reasonably well, and the final effluent contains about 10 p.p.m. suspended solids.

CONCLUSIONS.

Frequent, periodic examination of the sludge floc in a cell under a low power microscope is essential to obtain proper information concerning the condition of the sludge floc in its natural condition.

Bulking of activated sludge may be caused by diffuse floc structure, fungus growth or combinations of both.

Chlorination of the return sludge at low rates is a useful method for combating bulking due primarily to fungus growth. Results indicate that the proper rate of chlorination lies between either 0.7 and 7.0 p.p.m. of return sludge or .01 per cent and 0.1 per cent of the weight of dry solids, depending upon the character of the sludge floc.

Chlorination is not successful against that type of bulking due to light, diffuse floc.

Chlorination of an activated sludge is attended by the serious danger of overchlorinating and destroying the desirable plank-

ten growths. The margin of safety is small and use of the method requires constant, careful supervision.

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TABLE I.

EXPERIMENTS SHOWING THE EFFECT OF CHLORINE IN CONTROL OF SLUDGE BULKING RESULTING FROM FUNGUS GROWTH STATION W-20.

Exp. No.	Date	Aver. Amount Chlorine Used P.P.M. Net. Sludge	Aver. Amount Chlorine Used Perct. of Net.Sludge Dry Solids	Sludge Index	Sludge Blanket Percent of Sett. Tank Water Depth	Effluent Susp. Solids P.P.M.	Amount Fungus Present	Floc Condition
	12/3/34			4.3	100	149	Moderate	Ameboid. Ragged
		3.46						
1	12/9/34			5.3	89	128	Small	Ragged
		0						
	12/19/34			8.8	99	170	Small	Ragged
	12/17/34			8.8	99	170	Small	Ragged
		1.52						
2	1/7/35			10.1	14	18	0	Granular, Ameboid
		0						
	1/29/35			5.6	95	172	Trace	Ragged
	3/27/35			1.8	100	312	Mod.Abund	Spongy, Ragged
3		1.37	.04					
	5/14/35			2.4	39	10	Small	"
	6/6/35			1.8	79	108	Mod.Abund.	Ragged
4		2.12	.04					
	6/17/35			2.6	17	26	Small	Spongy, Ragged
	6/24/35			4.9	Less than 13	12	0 to Trace	Ameboid
5		1.68	.03					
	7/17/35			5.1	Less than 13	8	Trace	Spongy, Ragged
	9/21/35			3.8	90	24	Large	Large, [illegible]

13

	3/27/35			1.8	100	312	Mod.Abund.	Spongy, Ragged
3		1.37	.04					
	5/14/35			2.4	38	10	Small	"
	6/6/35			1.8	79	108	Mod.Abund.	Ragged
4		2.18	.04					
	6/17/35			2.6	17	34	Small	Spongy, Ragged
	6/24/35			4.9	Less than 13	13	0 to Trace	Amboid
5		1.68	.03					
	7/17/35			5.1	Less than 13	8	Trace	Spongy, Ragged
	9/21/35			3.8	90	26	Large	Large, Ragged, Dense
		.467	.007					
6	10/15/35			10.0	26	12	Moderate	"
		0	0					
	10/25/35			5.0	84	57	Large	"
	10/26/35			5.4	78	29	Large	Large, Ragged, Dense
7		.620	.008					
	11/5/35			13.9	13	8	Moderate	Large, Amboid

TABLE IX.

DETAILED OBSERVATIONS OF CHLORINE TREATMENT OF BULKING SLUDGE.

EXPERIMENT NO. 4.

Date	Chlorine Used P.P.M. Return Sludge	Chlorine Used Percent of Return Sludge Dry Solids	Sludge Index	Sludge Blanket Percent of Sett. Tank Water Depth	Effluent Susp. Solids P.P.M.	Amount Fungus Present
June 6,1935	2.02	.04	1.8	79	108	Mod. Abund.
7	2.73	.06	1.6	67	34	" "
8	2.73	.05	1.9	53	10	" "
9	2.59	.05	2.5	44	10	- - - -
10	2.74	.05	2.1	40	4	Mod. Abund.
11	2.57	.04	2.8	40	5	" "
12	1.60	.03	2.4	52	18	Small
13	1.70	.03	2.6	91	120	"
14	1.60	.03	2.5	92	92	Moderate
15	1.80	.03	3.3	80	28	"
16	1.79	.03	3.0	13	28	- - - -
17	1.60	.03	2.6	17	26	Small

Note; After June 15th, not enough sewage to supply plant. Trouble in street sewer.

TABLE III.

DETAILED OBSERVATIONS OF CHLORINE TREATMENT OF BULKING SLUDGE.

EXPERIMENT NO. 6.

Date	Chlorine Used P.P.M. Return Sludge	Chlorine Used Percent of Return Sludge Dry Solids	Sludge Index	Sludge Blanket Percent of Sett. Tank Water Depth	Effluent Susp. Solids P.P.M.	Amount Fungus Present.
Sept. 21, 1935	0.419	.0078	3.8	90	26	
22	.419	.0078	-	94	26	
23	.419	.0077	4.3	74	31	
24	.419	.0076	4.2	73	17	
25	.419	.0070	4.6	73	17	
26	.429	.0083	4.6	70	15	
27	.429	.0067	-	63	29	
28	.402	.0060	6.0	48	15	
29	.402	.0060	-	52	15	
30	.402	.0067	6.0	47	11	
Oct. 1, 1935	.402	.0068	4.7	50	17	Noticeable decrease
2	.402	.0062	6.1	54	13	
3	.402	.0054	6.1	57	19	Large
4	.402	.0057	6.3	51	12	
5	.402	.0042	6.6	58	18	
6	.402	.0042	-	42	18	
7	.402	.0055	7.0	68	21	Moderate
8	.402	.0057	6.1	85	46	"
9	.618	.0095	4.4	90	48	"
10	.690	.0112	5.4	80	18	"
11	.690	.0106	5.7	87	16	"
12	.690	.0098	6.4	48	17	Abundant
13	.690	.0098	-	34	17	- - - -
14	.690	.0123	8.6	26	11	- - - -
15	.690	.0099	10.0	15	12	Moderate
16	. 0	0	10.4	15	13	Mod. Abund.
17	0	0	10.2	50	15	- - - -
18	0	0	11.6	25	13	Small
19	0	0	10.6	34	13	Mod. Abund.
20	0	0	---	38	13	- - - -
21	0	0	8.7	25	11	- - - -
22	0	0	9.4	25	11	Mod. Abund.
23	0	0	8.5	31	13	" "
24	0	0	-	59	16	Large
25	0	0	5.0	85	97	"

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